Research Article

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Sexual Dimorphism and Age Estimation from the Lateral Cephalogram: A Non Invasive Technique

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ABSTRACT

Background: Sex determination and age estimation play an important role in forensic and anthropological science. For sex and age determination, there are two methods mainly 1) morphological and 2) laboratory method. Radiological techniques are morphological technique. Skull being a most stable part of the skeleton, details of the skull can be studied by lateral cephalograms. The study included 5 five linear cephalometric variables i.e. S-N, N-ANS, ANS- PNS, Co-Gn and ANS-Me for sex determination and age estimation.

Materials and methods: The study consisted of 84 Gujarati, Indian subjects comprising of 44 males and 40 females in the age range of 16-30 years. From the lateral cephalograms, 5 linear variables were taken and subjected to discrimination analysis for sex determination and regression analysis for age estimation. One way ANOVA was performed between the two sexes to see the age variation among the 3 age groups.

Results: In the present study, out of 5 linear cephalometric variables, 4 variables were highly significant ($p<0.05$) for sexual dimorphism except Co- Gn. For discrimination of sex, S-N was the most significant discriminator of sex (53.88%) while ANS-Me was least significant (7.2%). The derived discriminant function equation showed accuracy of 84.09% and 90% respectively in identification of males and females. One way ANOVA showed that S-N and N-ANS were highly significant variables among the 3 age groups for both the sexes. Regression analysis showed accurate age estimation between 16-25 years while discrepancy of 3 years or less in the age group of 26-30 years.

Conclusion: The lateral cephalograms are simple and accurate tool for sex determination and age estimation in contrast to costly and time consuming laboratory procedures. Also it can discriminate accurately between the two sexes.

Keywords: Lateral cephalogram, sexual dimorphism, Age estimation, One Way ANOVA.

INTRODUCTION

Forensic odontology had played an important role in the history of forensic science. History of forensic odontology starts with the creation of human life itself back to the Garden of Eden where bite marks were discovered in the remains of forbidden Apple and identified as of Adam and Eve. Bazar de la Charité fire, which occurred on May 4, 1897 in Rue Jean-Goujon, Paris in which 30 out of 126 persons were identified using dental findings by the Dr. Oscar Amoedo who is the Father of Forensic Dentistry. Dental evidence had identified many

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outstanding personalities like Raja Jaichand - last king of Kanauj, German dictator - Adolf Hitler, Pakistani General Zia- ul – haqq, as well as victims of terrorist attack on World Trade Centre in 2001 and Hurricane Katrina and Rita in 2005.[1]

Sex determination and age estimation play an important role in identification of either living or dead in case of mass disasters and air crash casualties. Apart from this, it is important in cases where decision depends upon the age of the culprit for ethical and humanitarian reason and for legal and criminal investigation. In these cases, forensic odontology helps to identify the deceased by using various methods. In current scenario, most of the methods are invasive while in very few studies non-invasive skeletal radiographic method has been used.[2] Pelvis is most commonly used skeletal part to identify a person, but it is mostly found in poor condition whereas skull is found in stable condition.[3] Scholars agree that sex determination can be performed easily and with high accuracy using skull. Methods used in sex determination and age estimation are of **two** types: **one** is morphological method which is quick and performed in "field" but it is less accurate. **Second** is biochemical method like aspartic acid racemization and DNA analysis, which is accurate but costly and time consuming.[4] Nowadays, one more method is applicable, i.e. use of radiograph of skeletal remains which seems to be very useful in cases of burn, decomposition and severe trauma where identification process is almost impossible. Dental radiography is an important part in forensic odontology. It is quicker, cheaper, non-invasive and readily available tool as compared to other costly and complicated methods. Age estimation of the deceased is the most difficult one, but is an essential part of reconstructive information from skeletal remains. Lateral cephalograms are valuable tool in sex determination and age estimation as they reveal architectural and morphological details of the skull on a single radiograph.[5] In literature, very few studies have been done on age estimation using the lateral cephalogram. Hence, in the present study we emphasize to find out the specificity and utility of some of the linear cephalometric variables for sex determination and age estimation in forensic cases.

Objectives of this study were:

1) To determine sexual dimorphism from five linear cephalometric variables

2) To estimate the age from five linear cephalometric variables

MATERIAL AND METHOD

The study was carried out on a total of 84 subjects of Gujarat state, India. Lateral cephalograms were obtained from the files of Orthodontia Department, Government Dental College and Hospital, Ahmedabad from the time period of January 2014 to April 2015. Included subjects were 44 males and 40 females with the age range of 16- 30 years. They were divided in 3 groups according to age range. Group 1and Group 2 consisted of 30 subjects each in the age range of 16-20 years and 21-25 years respectively while Group 3 consisted of 24 subjects in the age range of 26-30 years. From the records, subjects with prior history of orthodontic and orthognathic treatment, trauma, surgery of skull, developmental disturbances, facial asymmetry and prolonged illness were excluded from the study.

Lateral cephalograms of the study subjects were obtained by using Planmeca 2002 cc Proline Panoramic Unit of the Orthodontia department having teeth in centric occlusion. For this study, following 5 linear variables from the craniofacial compartment were derived from the bony landmark:

1) Sella to Nasion (S-N) depicted as Anterior Cranial Base
2) Nasion to Anterior Nasal Spine (N-ANS) depicted as Upper facial height
3) Anterior Nasal Spine to Posterior Nasal Spine (ANS-PNS) depicted as palatal plane
4) Condylion to Gnathion (Co-Gn)
5) Anterior Nasal Spine to Menton(ANS-Me) depicted as Lower facial height

Above mentioned cephalometric variables were transcribed onto acetate sheets by tracing with the help of an X-ray viewer using 0.5 mm lead pencil by one investigator and checked for the accuracy by the second. The magnification of each film was available in the database and was standardized to an 8% enlargement factor.

Linear variables were measured and data was subjected to statistical analysis using SPSS software

(IBM) version 15.0. Discriminant function analysis was used to assess the efficacy of the selected cephalometric variables in the discrimination of the two sexes. One way ANOVA was performed between the two sexes to see the age variation among the age groups. Regression analysis was performed for age estimation and accuracy of the derived functions was determined.

RESULTS

Descriptive statistical analysis was carried out in this study for 5 linear cephalometric variables and were subjected to Student t-test to find out the significance of these variables on continuous scale between two sexes at p value <0.05. Results on continuous measurements were presented in **Table 1** as Mean and SD. Out of 5 variables, 4 variables were highly significant for sexual dimorphism except Co-Gn.

5 variables were subjected to discriminant functional analysis to test their efficacy in differentiating the two sexes. As shown in **Table 2,** out of 5 variables, 4 were highly predictable for the determination of the sexes except one variable ANS-Me. The most predictable variable was S-N (>50%).

Discriminant function equation was derived using coefficient of cephalometric variables. Reliability of derived discriminant function was assessed for the sex determination among study subjects from which 84.09 % of males were identified as males and 90% of females were identified as females with average score being 87% as shown in **Table 3**.

One way ANOVA was performed between the two sexes to determine the age variation among the age groups of the study subjects using 5 linear cephalometric variables. The subjects were in the age range of 16-30 years and were divided into 3 age groups 16-20 years, 21-25 years and 26-30 years. Out of 5 variables, 2 variables S-N and N-ANS were highly significant at p value <0.05 both for males and females whereas variable Co-Gn was significant only for the females. The S-N and Co-Gn subsequently decreased with age as shown in **Table 4**.

For age estimation, regression analysis was performed using each variables and estimated age was derived for each individual which showed standard error of estimate of 3.13 years. (**Table** 5)

Table 1: Descriptive statistics and p value of cephalometric linear variables.

VARIABLE	MALES (n=44)			FEMALES (n=40)			p-value
	MEAN	SD	SEM	MEAN	SD	SEM	
S-N	65.64	2.93	0.442	62.10	3.81	0.603	<0.005
N-ANS	46.23	1.99	0.300	44.80	3.01	0.475	0.011
ANS-PNS	50.64	2.66	0.401	45.65	1.85	0.292	<0.005
Co-Gn	107.36	15.42	2.325	103.83	5.09	0.805	0.170
ANS-Me	61.64	3.58	0.540	57.20	4.90	0.775	<0.005

Table 2: Discriminant function analysis of cephalometric linear variables.

VARIABLE	MALES		FEMALES		t value	Std. coefficient	%
	MEAN	SD	MEAN	SD			
S-N	65.64	2.934	62.10	3.815	4.787	0.059	53.88
N-ANS	46.23	1.987	44.80	3.006	2.589	0.057	30.88
ANS-PNS	50.64	2.660	45.65	1.847	9.884	0.07	19.85
Co-Gn	107.36	15.423	103.83	5.093	1.383	0.111	32.96
ANS-Me	61.64	3.583	57.20	4.900	4.766	0.08	7.2

Table 3: Sex discrimination classification results.

STUDY GROUPS	Total	Predicted Group Membership			
		MALE		FEMALE	
		No.	%	No.	%
MALE	44	37	84.09	7	15.91
FEMALE	40	4	10	36	90

Table 4: One way ANOVA test among 3 study groups for age variation.

VARIABLE	MALES (n=44)			FEMALES (n= 40)		
	16-20 YEARS	21-25 YEARS	26-30 YEARS	16-20 YEARS	21-25 YEARS	26-30 YEARS
	MEAN±SD	MEAN±SD	MEAN±SD	MEAN±SD	MEAN±SD	MEAN±SD
S-N	67.37 ±3.20	65.12± 2.63	64 ±1.60	65.07± 2.58	62.5 ±3.13	58.16 ±1.95
	P value- 0.0049			P value- 0.0014		
N-ANS	47.5 ±1.86	44.87 ±3.83	46.33 ±0.99	46.64 ±3.89	43.07 ±1.90	44.67 ±1.30
	P value- 0.0003			P value- 0.0148		
ANS-PNS	49.62± 2.75	50.75 ±1.86	51.84± 1.75	44.93± 1.82	43.07± 1.90	45.67 ±2.14
	P value- 0.0896			P value- 0.1223		
Co- Gn	110.32 ±5.33	109.5 ±3.61	108.84 ±2.86	105.14 ±5.63	105.5 ±5.40	100.33 ±0.98
	P value- 0.6459			P value- 0.0136		
ANS-Me	61.12± 4.16	63.25 ±2.81	60.16± 3.04	57.07 ±3.58	58.35 ±7.11	56 ±2.63
	P value- 0.0576			P value- 0.4816		

Table 5: Regression analysis for age estimation.

Regression Equation	r^2	Standard Error of Estimate
Age =61.66 -0.679*S-N - 0.413*N-ANS +0.477*ANS-PNS +0.00905*Co-Gn-0.0203*ANS-Me	0.456	3.13 years

DISCUSSION

Determining the sex and age of deceased persons is one of the most important aspects of medico legal investigation and anthropological research. For this purpose use of simple, economic, quick, nondestructive and accurate modalities can reduce the time in identification of an individual. The need has increased for such modalities due to increased mass fatality incidences across the world either in the form of natural calamities, accidents or criminal cases. In all such cases identification of skeletal remains hold prime importance. The recognition of sex forms an important aspect in the individual identification. Sexual dimorphism is the expression of secondary sexual characteristics that are defined after puberty and during adolescent years.[6] After pelvis, skull is the most easily sexed portion of the skeleton [3] and angular and linear measurements of skull provides 80-100% accuracy for differentiation of sex. When attempting to match unidentified remains against hundreds of missing individuals, age estimation is an important part of every identification process relating to the deceased. Apart from this, it is important in criminal and accidental cases. Skull and teeth provide a lot of information about age at death.

At present the radiological method being a non-invasive technique, provide fairly accurate sex and age determination from skeletal remains of young adults.[2] Cephalograms are favored for craniofacial assessments as they are more objective and highly reproducible which reveal architectural and morphological details of the skull on a single radiograph.[5] In case of intact skull, the angular measurements depict a "pattern" [7] but challenge lies to identify an individual with mutilated body parts along with craniofacial complex. In such scenario, linear cephalometric measurements contribute to sex and age assessment with high accuracy. In the present study, 5 linear cephalometric variables i.e S-N, N-ANS, ANS-PNS, Co-Gn and ANS-Me were measured for determination of sex and age. We noted that all the variables except Co-Gn were highly significant (p value <0.05) for sexual dimorphism while Co- Gn appeared least reliable variable. Chang et al (1993)[8] reported that although the craniofacial growth pattern among the two sexes is essentially the same, sexual dimorphism observed is the result of early attainment of skeletal maturity in females as compared to males that can be justified by the findings of the present study where measurements were greater in males as compared to females which is also in accordance with the findings of other studies.[9-12]

The derived discriminant function used for differentiation of male and female in the present study showed that all the variables were useful for sex determination. The variables S-N, Co-Gn, N-ANS, ANS-PNS and ANS-Me showed their discriminative powers 53.88%, 32.96%, 30.88%, 19.85% and 7.2% respectively. Among these variables, S-N was the most significant and useful variable while ANS-Me was the least useful variable which was also reported by Naikmasur et al[10] who noted that lower facial height (distance from ANS-Me) contributed the least for sexual dimorphism in Tibetan population. The findings of the present study were quite contrasting with the findings of Binnal A[13] who noted that N-ANS was not reliable variable to determine sex by seeing their discriminative power as 0.61% in her study. Sex predictability was determined by using 5 linear cephalometric variables in the present study which was 87% accurate in differentiating the male and female subjects and was quite similar with Binnal A[13] who noted 86% accuracy in differentiating the male and female subjects. It was consistent with the finding of Naikmasur et al[10] who showed accuracy of 81.5% and 88.2% for Indian and Tibetan populations respectively. In the present study, males were identified as males in 84.09% while females were identified as females in 90% cases which showed that females can be more accurately identified with these variables which were also reported by T.Hsiao et al [7] and Bibby [9] but findings of Binnal A[13] were contrasting who noted that males were more accurately identified than females.

In the age group of 16-30 years, the age variations showed by One way ANOVA test indicated significant changes in S-N and N-ANS by using 5 variables in the present study whereas changes observed in ANS-PNS, Co-Gn and ANS-Me according to age were non-significant. These changes were observed before and after the puberty and continued even up to the age of 30 years. The changes in S-N and N-ANS according to age might be due to difference in somatic and neural growth patterns. Also nasion is the part of frontal bone which increases in thickness by surface deposition during life accompanied by pnuematization of frontal sinus[14]. ANS-PNS showed continuous increase from 16-30 years for both the sexes in the present study but was non-significant. As with the growth, maxilla maintained constant relationship and presented a coordinated forward displacement relative to the cranial base but according to Weber et al[12], this increase was not evident in females of more than 14 years as growth has ceased to final size. In the present study, ANS-Me non-significantly increased up to the age of 25 years in both males and females which was also reported by McNamara[11]. There was non-significant decrease in Co-Gn according to age for males whereas females showed significant decrease only between 26-30 years.

In the present study, age can be estimated by using all 5 cephalometric linear variables accurately up to the age of 25 years and with the discrepancy of 3 years in the age group of 26-30 years by the regression analysis. Thus, regression analysis demonstrated that the use of a single variable was insufficient for accurate age determination. However, combination of variables showed the best goodness of fit (r^2). In the study of Kvaal et al[2] and Azrak et al[15] , there was discrepancy of 9 years and

15 years respectively to estimate the age which may be due to difference in variables and methods used in their study and of the present study.

CONCLUSION

In the forensic investigation, even though intact skull may not be available, any of the linear variables of the present study can contribute to sexual dimorphism and age estimation accurately up to the age of 25 years and with the discrepancy of 3 years in the age group of 26-30 years. Also, in the present study, variations among the 3 age groups were shown by using one way ANOVA test between males and females.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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